(12) UK Patent Application (19) GB (11) 2 037 444 A

(21) Application No 7941597
(22) Date of filing 3 Dec 1979
(30) Priority data
(31) 7834151
(32) 4 Dec 1978
(33) France (FR)
(43) Application published 9 Jul 1980
(51) INT CL[3] G01L 5/00 // B66C 23/36 G01L 1/22
(52) Domestic classification G1W E2A1 E2A2 E2A3 E3D1 E3D611X
(56) Documents cited None
(58) Field of search G1W
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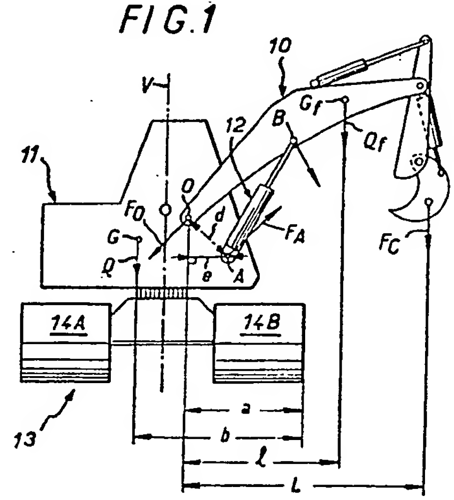
(54) Force measuring dynamometric device for a load handling machine

(57) A dynamometric device for monitoring tilting of load handling machine having a jib (10) pivoted on a chassis (11) and operated by a jack (12), comprises two force-detecting spindles each bearing strain gauges disposed in such a way as to be sensitive only to shearing stresses, the one acting as a pivot O between the jib (10) and the chassis (11), the other acting as a pivot A or B between the jack (12) and the chassis (11) or the jib (10) respectively, the spindles being orientated so that their strain gauges are disposed in planes P_1, P_2 which are at right-angles to the plane containing the geometric longitudinal axes of the spindles. The device may also be used to measure the load F_c applied to the jib (10).

FIG.1



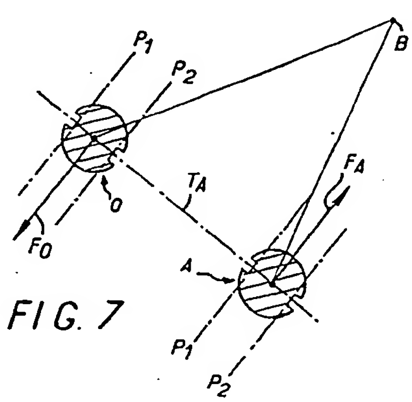


FIG. 7

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FIG.1

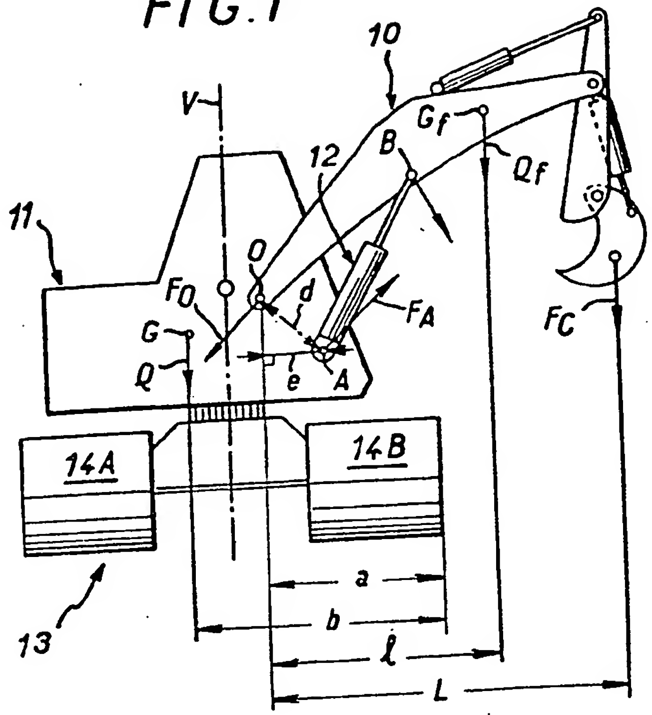


FIG.2

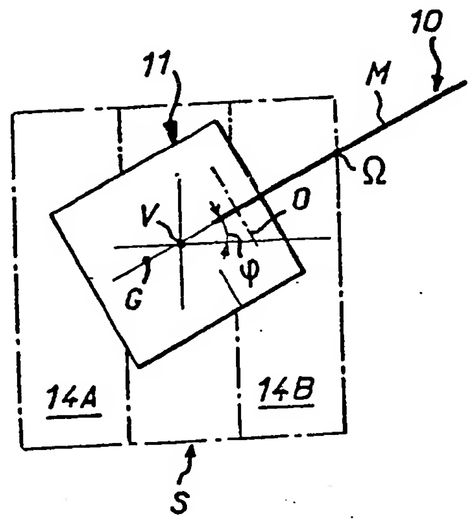


FIG.3

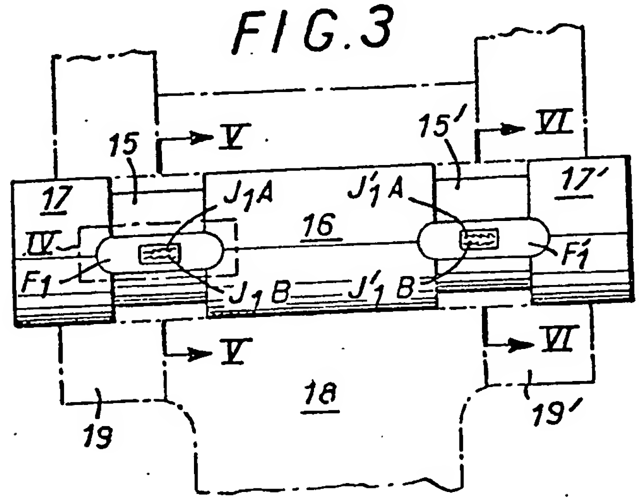


FIG.5

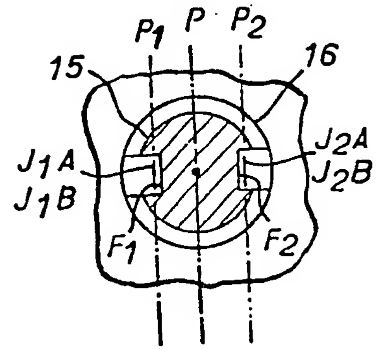


FIG.4

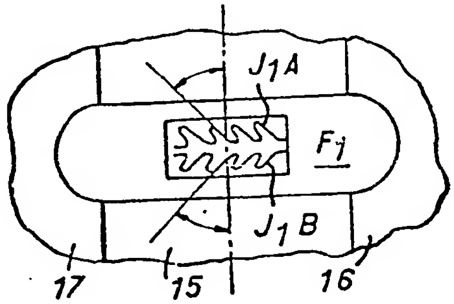
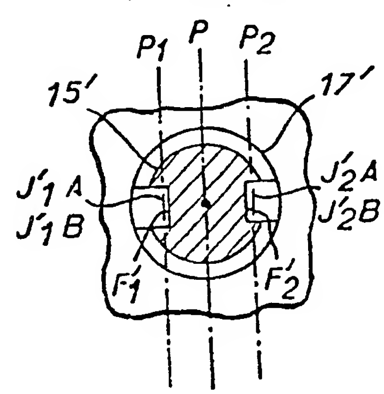


FIG.6



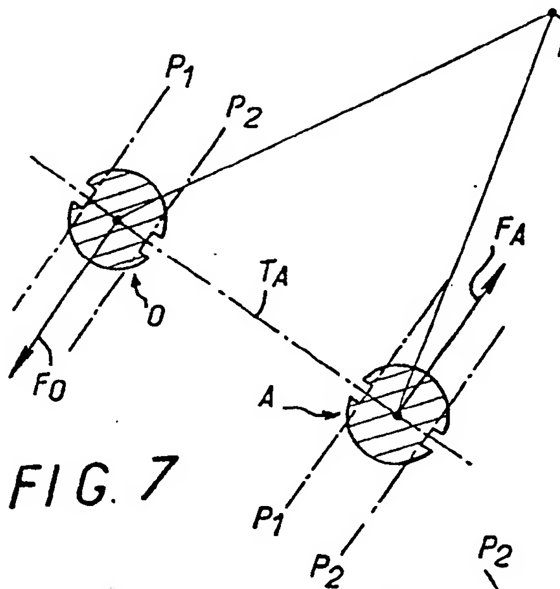


FIG. 7

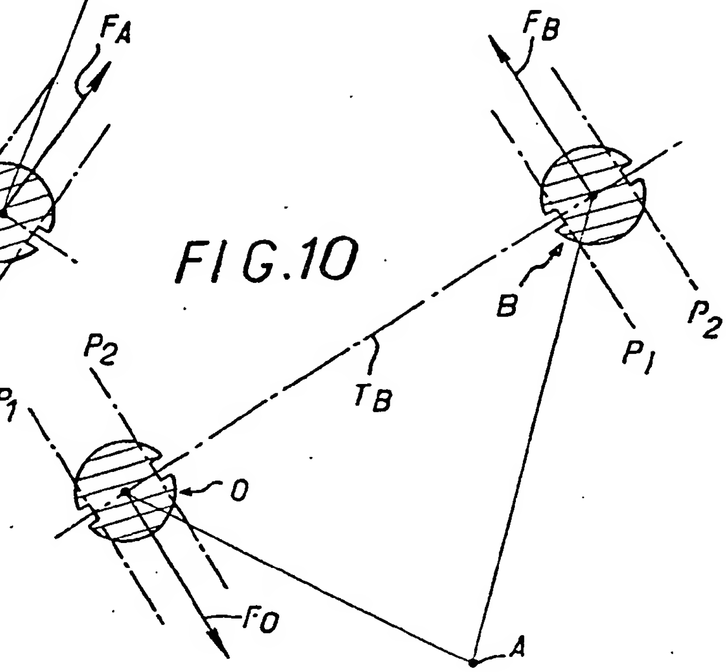


FIG.10

FIG.8

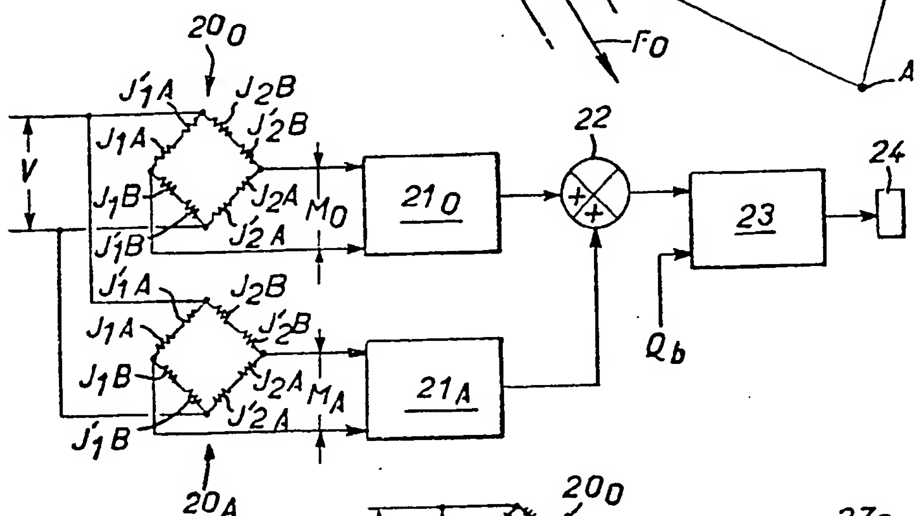
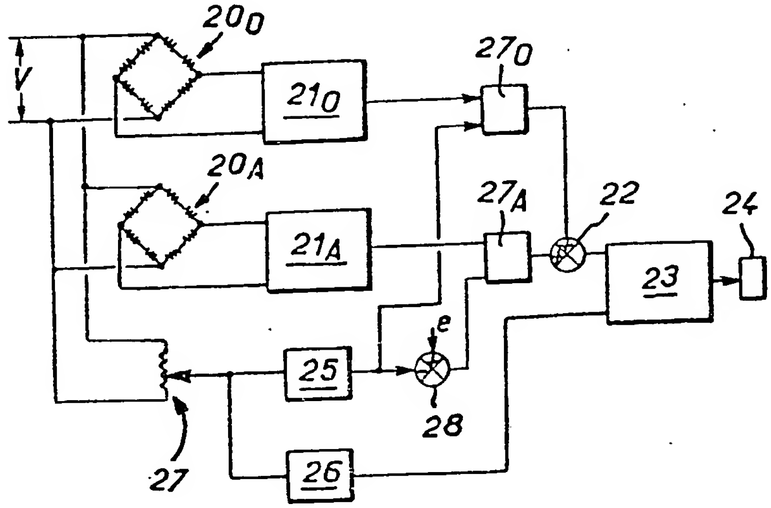


FIG.9



SPECIFICATION

Force measuring dynamometric device for a load handling machine

The invention relates to a dynamometric device for measuring forces acting on a load handling machine having a jib, and, more particularly, for monitoring the stability of such a machine.

The French Patent filed under No. 75 33499 and published under No. 2 346 278 described a dynamometric device for a jib of a lifting mechanism, which device comprises a spindle acting as a pivot between two members of the mechanism and constituting a force gauge. This spindle is keyed to one of the member in a specific angular orientation relative thereto and bears two sets of strain gauges lying in two respective substantially parallel planes and disposed in such a way as to be sensitive only to shearing stresses.

In this French Patent, such a force-detecting spindle is used for measuring a torque which, associated with a measurement of length, relative to the length of the jib and a measurement of angle relative to the angle of inclination of this jib, makes it possible to determine a load curve according to the radius of the jib, this radius being defined as the horizontal distance between the vertical at the pivot point of the jib and that at the point of the jib at which a load is applied. This load curve is not necessarily that of the limit overturning torque, because it likewise takes into account limits of mechanical strength of the jib and of the other members associated therewith. But a single force-detecting spindle is sufficient in this case for the torque measurement carried out.

However, in cases in which only the limiting turnover torque can be taken into account in order to establish the load curve, it is not necessary *a priori* to know the radius of the jib and it is therefore advantageously possible to dispense with both corresponding length and angle measurements as well as calculations for determining the radius from such measurements. However, the use of a single force-detecting spindle is no longer sufficient; two must be used.

A suggestion is made along these lines in the French Patent filed on 12th January, 1976 under No. 76 00595 and published under No. 2 315 690. But in this French Patent there is provision for resolution of forces into horizontal and vertical components, which gives rise to certain drawbacks.

First of all, two measurements are needed for each force-detecting spindle, which results in a fairly complicated arrangement. Furthermore, because horizontal components are taken into account the measurements are affected by a possible "settlement" of the mechanism as a result of the load stresses, i.e. sinking of the body of the mechanism, caused by this load which does not fail to produce a certain amount of compression of the suspension normally linking the body with the associated translational means, or perhaps even of the translational means itself, if it comprises tyres.

Similarly, but to a lesser degree, the measurements carried out are affected by a possible lack of horizontally of the said body, which results from taking into account vertical components.

Finally, the force-detecting spindles employed are not sensitive just to shearing stresses but to bending stresses which normally necessitates precise definition (a condition which in practice it is impossible to comply with) of the points where these force-detecting spindles are acting on the members between which they function.

The object of the present invention is generally to provide a dynamometric device having two force-detecting spindles and in which these drawbacks are minimised.

According to the invention, there is provided a dynamometric device for a load handling machine having a jib mounted for pivotal movement on a chassis and operated by jack means which is itself mounted for pivotal movement both on the chassis and on the jib, the device comprising two force-detecting spindles each acting as a pivot between two members, a first between the jib and the chassis and a second between the jack means and either the chassis or the jib, each of the force-detecting spindles being keyed to one of the members between which it acts as a pivot so as to be at a specific angular orientation with respect to the said one member, bearing two sets of strain gauges lying in two respective substantially parallel planes and disposed in such a way as to be sensitive only to shearing stresses, the planes being at right-angles to the plane which contains the geometric longitudinal axes of both the force-detecting spindles.

Indeed, calculation shows that it is thus possible at any time to monitor whether the load handling machine complies with the stability equation, and hence to avoid the machine tipping, for example by the systematic operation of any warning device when this stability equation is on the point of being no longer satisfied.

In practice, the stability equation comprises coefficients which vary with the orientation of the chassis on which the jib is pivoted, when this chassis is itself mounted to rotate about a vertical axis.

As a preliminary approximation, it may suffice to give these coefficients their minimum values.

Preferably, however, the device further comprises an operator which, guided by a sensor which is sensitive to the angular orientation of the rotating chassis, modulates accordingly the measurements taken by the strain gauges of the force-detecting spindles.

In all cases, the device according to the invention makes it possible, when monitoring tilting, to dispense both with the two unknown factors which are at any time the load applied to the particular jib and the radius of this jib, as well as with any settlement of the machine having the jib and/or any lack of horizontally of the body of the appliance.

Furthermore, these force-measuring spindles

will, if desired, enable absolute measurement of the load for comparison with a limit which must not be exceeded, in the case of such a limit having to be observed in order for example to avoid deformation, or even breakage of the jib, even outside the conditions for possible tilting of the machine having the jib.

Thus, the dynamometric device having two force-detecting spindles according to the invention is suitable both for monitoring the tilting of an appliance having a jib articulated on a chassis and for measuring the load applied to the jib.

Embodiments of the invention will now be described, by way of example only, and with reference to the accompanying diagrammatic drawings in which:—

Fig. 1 is an elevational view of a load handling machine to which a dynamometric device according to the invention is applied;

Fig. 2 is a diagrammatic plan view of this machine;

Fig. 3 shows on an enlarged scale an elevational view of a force-detecting spindle of the dynamometric device according to the invention;

Fig. 4 shows, on an enlarged scale, a detail of Fig. 3 indicated by the area IV on the latter;

Figs 5 and 6 are cross-sectional views through the force-detecting spindle respectively on the lines V—V and VI—VI of Fig. 3;

Fig. 7 is a diagrammatic representation, in elevation according to Fig. 1, of the machine to which the dynamometric device according to the invention is applied, to illustrate the orientation of the force-detecting spindles which this device comprises;

Fig. 8 is a block diagram showing the electric assembly of the dynamometric device according to the invention;

Fig. 9 is a block diagram similar to that in Fig.8 but relating to an alternative embodiment; and

Fig. 10 is a diagrammatic representation similar to that in Fig. 7 showing an alternative manner of implementing the invention.

Figs. 1 and 2 illustrate the application of the invention to any load handling machine generally comprising a lifting jib 10 pivoted about a horizontal axis O on a chassis 11 under the control of jack means 12 itself pivoted at one of its ends on the chassis 11 about a horizontal A and at its other end on the jib 10 about a horizontal axis B.

The machine in question may for example be a hydraulic crane or a hydraulic digger. Since the design of such a machine is not in itself part of the present invention, it will not be described in detail here.

It is sufficient to stipulate that in practice the chassis 11 is mounted to rotate about a vertical axis V on a base 13, which includes translational means comprising, for example, two sets of translational means 14A, 14B, such as caterpillar tracks, which together define a support polygon S for the machine, the polygon being bounded by chain-dotted lines in Fig. 2. In Fig. 2, the jib 10 is represented by a line corresponding to the trace of its mean vertical plane M. A vertical load F_c is applied, by methods which are not part of the present invention, to the jib 10.

The stability equation of the particular machine is:—

$$F_c \,.\, (L - a) + Q_f \,.\, (l - a) \leqslant Q.b \qquad \text{(I)}$$

in which:

F_c is the load applied to the jib,

L is the "radius" of the jib, i.e. the horizontal component in the vertical plant containing the jib 10 of the distance from the axis O to the point at which the load F_c is applied to the jib,

Q_f is the weight of the jib 10 assumed to be concentrated at the centre of gravity G_f thereof, l is the horizontal component in the vertical plane containing the jib 10 of the distance from axis O to the centre of gravity G_f of the jib,

Q is the weight of the part of the machine formed by the rotating chassis 11 and the base 13, i.e. excluding the jib 10, this weight being assumed to be concentrated at the centre of gravity G of this part of the machine, G being assumed to lie in the mean vertical plane M of the jib 10, and

a and b are the horizontal distances, in the plane M, from the pivot axis O and from the centre of gravity G, respectively, to the point of intersection Ω of the boundary of the corresponding supporting polygon S and the plane M.

There are two unknown factors in the above stability equation (I). The first, the load F_c, has a direct influence, whilst the second, the position of the jib 10 in space, is indirectly important, by virtue of its effect on the distances L and l.

In order to resolve the stability equation (I), and hence to monitor tilting of the particular machine in question, the device of the present invention comprises two force-detecting spindles of the same type as those described in French Patent No. 2 346 278 mentioned hereinabove.

Such a force-detecting spindle is illustrated in isolation in Figs. 3 to 6. It comprises adjacent each of its ends a portion of reduced diameter 15, 15′, each of which extends between two portions of greater and common diameter, that is to say a middle portion 16 and one of two end portions 17, 17′.

Arranged axially of the spindle, in the region of its portions of reduced diameter 15, 15′, and lying substantially in two planes P_1, P_2 parallel with one and the same axial plane of symmetry P, such a force-detecting spindle carries two sets of strain gauges J_1, J_2, as detailed hereinafter.

For each plane P_1, P_2, the sets of strain gauges J_1, J_2 each comprise two groups J, J′ of at least two strain gauges, each group being respectively associated with the portions of reduced diameter 15 and 15′.

Thus, in the example of embodiment illustrated, the portion of reduced diameter 15 comprises, on

a face F_1 which extends substantially in the plane P_1 and the ends of which abut the portions of larger diameter 16, 17, a group J of two strain gauges J_{1A}, J_{1B}.

These strain gauges are disposed in such a way as to be sensitive only to shearing stresses. For example, and as illustrated in Fig. 4, the strain gauge J_{1A} is inclined at 45° relative to the plane which is at right-angles to both the axial plane of symmetry P and to the geometric longitudinal axis of the force-detecting spindle in question, and a strain gauge J_{1B} which is likewise inclined at 45° relative to this plane, but at 90° to the strain gauge J_{1A}.

According to a similar arrangement, the portion of reduced diameter 15 also carried on a face F_2 lying substantially in the plane P_2 a group J of two strain gauges J_{2A}, J_{2B}, and the portion of reduced diameter 15′ carries, on faces F'_1, F'_2 disposed respectively in planes P_1, P_2, a group J′ of two strain gauges J'_{1A}, J'_{1B}, and a group J′ of two strain gauges J'_{2A}, J'_{2B}.

The faces F_1, F_2, F'_1, F'_2 may be substantially flat; they may instead be curved faces.

According to the invention, two such force-detecting spindles are employed together, a first acting as the pivot O between the jib 10 and the chassis 11, the second as the pivot between the jack means 12 and either the chassis 11 or the jib 10, i.e. A or B respectively.

For example, and according to the embodiment illustrated in Fig. 7, this second force-detecting spindle forms the pivot A between the jack means 12 and the chassis 11.

The force-detecting spindle O is as indicated by broken lines in Fig. 3, with its middle portion 16 engaged in a socket 18 rigid with the jib 10, while its end portion 17, 17′ engage flanges 19, 19′ a plate rigid with the chassis 11.

The socket 18 in the jib 10 extends partly beyond the portions of reduced diameter 15, 15′ of the force-detecting spindle O as do the flanges 19, 19′ in the plate rigid with the chassis 11.

As shown in Fig. 8, there is associated with such a force-detecting spindle O a Wheatstone bridge 20_0, of which each arm comprises in series two strain gauges working in the same direction, whether this relates to traction work or to compression work.

For example, and as illustrated, the strain gauges J_{1A}, J'_{1A} are in series in one and the same arm of this Wheatstone bridge and the same applies respectively to the strain gauges J_{1B}, J'_{1B}, J_{2A}, J'_{2A} and J_{2B}, J'_{2B}. A supply voltage V is applied to one of the diagonals of the Wheatstone bridge 20_0 while a measuring voltage M_0 is collected from the other diagonal.

The end portions 17, 17′ of the force-detecting spindle O are keyed to the flanges 19, 19′ respectively of the chassis 11, for example by means of keys not shown, and the angular orientation which it is thus given is such that, as illustrated in Fig. 7, its planes P_1 and P_2 are at right-angles to the plane T_A which contains both its geometric longitudinal axis and the geometric longitudinal axis of the force-detecting spindle A with which it is associated. Under these conditions, and as indicated particularly in French Patent No. 2 346 278 mentioned hereinabove, the measuring voltage M_0 given by the Wheatstone bridge 20_0 is a measure of the component F_0, at right-angles to the plane T_A, of the resultant at O of the forces to which the machine is subjected.

The equilibrium of moments about the geometric longitudinal axis of the force detecting spindle A of the whole of these forces therefore allows us to write the following equation, (Fig. 1):—

$$F_0 \cdot d - Q_f (l - e) - F_C (L - e) = 0 \tag{II}$$

in which d is the distance, between geometric axes through the force-detecting spindles O and A, and e is the horizontal component of the distance d.

The force-detecting spindle A is of a similar construction to that of the force-detecting spindle O and, in a similar manner, it is keyed to the chassis 11 in a specific angular orientation for which, as illustrated by Fig. 7, its planes P_1, P_2 are likewise at right angles to the plane T_A containing the geometric longitudinal axes of the force-detecting spindles O and A.

Under these conditions, the measuring voltage M_A collected on the Wheatstone bridge 20_A associated with the force-detecting spindle A, Fig. 8, is a measure of the component F_A, at right-angles to the plane T_A, of the resultant, at the point A, of all the forces to which the particular machine is subjected, and by balancing the moments, about the axis O, of all these forces makes it possible to write the following equation:

$$F_A \cdot d - Q_f \cdot l - F_C \cdot L = 0 \tag{III}$$

By deducting the equation (II) from the equation (III), we arrive at the following new equation (iV):—

$$F_A - F_0 = \frac{e}{d} (Q_f + F_C) \tag{IV}$$

By applying the equations (III) and (IV) to the stability equation (I) hereinabove, a new expression (V) is obtained as follows, for the stability equation, as a function of the components F_0 and F_A:—

$$F_A \cdot d \cdot \left(1 - \frac{a}{e}\right) + \frac{ad}{e} \cdot F_0 \leqslant Q \cdot b \tag{V}$$

In this expression, the coefficient d is a constant. The coefficient e may also be considered to be constant, because the distance which it

represents, which normally depends on the attitude of the particular machine, i.e. the inclination of its base 13 in relation to the horizontal varies very little in practice as a function of this attitude, which itself varies very little.

The coefficients *a* and *b* are variables, however, because the distances which they represent vary with the orientation of the rotating chassis 11 about its vertical axis V, that is to say according to the angle ψ represented in Fig. 2.

According to a first embodiment of the invention, illustrated in Fig. 8, it is however accepted that these coefficients *a*, *b* are constant, assuming for them the minimum value of the corresponding distances which enables with complete safety to meet the stability equation of the machine.

Under these conditions, the device according to the invention may amplify the measuring voltage M_0 delivered by the Wheatstone bridge 20_0 with an amplifier 21_0 of gain equal to *ad*, and, amplify the measuring voltage M_A delivered by the Wheatstone bridge 20_A, with an amplifier 21_A of gain equal to *d*.

$$(1-\frac{a}{e}).$$

It may also comprise an adder 22, which effectively receives at each of its inputs the voltages which are thus processed, a comparator 23 which receives the output voltage from the adder 22 as well as a reference voltage which is a measure of the value $Q{\cdot}b$ of the stability equation (V). Finally, if desired, it may comprise a signalling means 24, visual or acoustic for example, which is operated by the comparator 23.

The practical implementation of the components 21, 22, 23 and 24 mentioned hereinabove falls within the scope of a man skilled in the art and therefore will not be described in detail here.

As soon as the signal from the comparator 23 attains a given critical value indicating imminent non-compliance with the stability equation of that particular machine, the signalling means 24 comes into operation. If desired, it may act directly on the jack means 12 in order to interrupt or to reduce the work thereof and so limit the load applied to the jib 10.

According to the alternative embodiment illustrated in Fig. 9, two operators 25, 26 are employed which are guided by a sensor 27 which is sensitive to the orientation ψ of the pivoting chassis 11, and which are hence capable of modulating the voltages delivered by the Wheatstone bridges 20_0, 20_A as a function of the structural disposition of the particular machine prior to these voltages entering the adder 22.

In practice, the operator 25 is used to calculate at any moment the coefficient *a* as a function of the orientation ψ and the operator 26 is used to calculate at any moment the term Q.*b* as a function of this orientation.

Jointly, the amplifier 21_0 and 21_A are chosen such that both the one and the other should have only a gain equal to

$$\frac{d}{e}.$$

A multiplier 27_0 receives simultaneously the output voltages of the amplifier 21_0 and the operator 25 and, likewise, a multiplier 27_A simultaneously receives the output voltage of the amplifier 21_A and the output voltage of a subtractor 28, which in turn receives at each of its inputs a voltage which is a measure of the coefficient *e* and the output voltage of the operator 25.

The adder 22 receives the output voltages of the multipliers 27_0 and 27_A.

The comparator 23 receives both the output voltage of the adder 22 and the output voltage of the operator 26.

As in the previously described embodiment, the comparator operates the signalling device 24.

According to the alternative embodiment illustrated in Fig. 10, it is the pivot axis B between the jack means 12 and the jib 10 where a force-detecting spindle is located, instead of having the aforementioned spindle located at axis A.

In this case, the angular orientation of the force-detecting spindles O and B is such that their planes P_1, P_2, in which their strain gauges lie, are at right-angles to the plane T_B which contains their geometric longitudinal axes and the force-detecting spindle B is keyed to the jib 10 in this particular orientation. As previously, the balance of moments about these axes makes it possible according to the invention to monitor tilting of the particular machine.

However, the embodiment illustrated in Fig. 7 is preferred because the force-detecting spindles are then both fixed in space.

The same does not apply to the embodiment shown in Fig. 10 for which the force-detecting spindle located at axis B on the jib moves with this latter, which normally implies knowledge of the inclination of this jib in order to calculate the horizontal distance between the vertical of its axis and that of the axis O.

Nevertheless, the force-detecting spindles employed according to the invention may, if desired, enable absolute measurement of the load to which the jib of the particular machine is subjected.

Indeed, it may be interesting, particularly when the jib 10 is occupying a position close to the vertical, to limit the load which is applied to it since this load, although it is not then likely to cause the machine to tip over, may, if it is too high, cause deformation of the jib or even breakage thereof.

From the equation (IV) above, it is possible to extract the load F_C as follows:

$$F_C = (F_A - F_0)\frac{d}{e} - Q_f \qquad \text{(VI)}$$

According to methods similar to those described hereinabove, it is possible to compare this load with the tolerated, limit for the jib 10 and, if desired, to operate some signalling or warning device accordingly.

In any case, the force-detecting spindles according to the invention preferably each have an external reference marking which makes it possible to check by sight their angular orientation; it may be, for example, a single line (not shown in the drawings).

Clearly, the present invention is not confined to the embodiments which have been described and illustrated, but includes all possible alternative embodiments.

CLAIMS

1. A dynamometric device for a load handling machine having a jib mounted for pivotal movement on a chassis and operated by jack means which is itself mounted for pivotal movement both on the chassis and on the jib, the device comprising two force-detecting spindles each acting as a pivot between two members, a first between the jib and the chassis and a second between the jack means and either the chassis or the jib, each of the force-detecting spindles being keyed to one of the members between which it acts as a pivot so as to be at a specific angular orientation with respect to the said one member, and bearing two sets of strain gauges lying in two respective substantially parallel planes and disposed in such a way as to be sensitive only to shearing stresses, the planes being at right-angles to the plane which contains the geometric longitudinal axes of both the force-detecting spindles.

2. A device according to Claim 1, in which the first force-detecting spindle is keyed to the chassis.

3. A device according to Claim 1 or Claim 2, in which the second force-detecting spindle is provided between the jack means and the chassis and is keyed to the chassis.

4. A device according to Claim 1 or Claim 2, in which the second force-detecting spindle is provided between the jack means and the jib and is keyed to the jib.

5. A device according to any one of Claims 1 to 4, in which each of the force-detecting spindles has an external reference mark enabliing its angular orientation to be assessed.

6. A device according to any one of Claims 1 to 5, in which the strain gauges are mounted on a Wheatstone bridge provided for each of the force-detecting spindles, the device further comprising an adder which receives at each of its inputs the voltages delivered by the measuring diagonals of each Wheatstone bridge and a comparator which receives both the output voltage of the adder and a reference voltage.

7. A device according to Claim 6, further comprising a signalling means operated by the comparator.

8. A device according to Claim 7, in which the signalling means is visual or acoustic.

9. A device according to any of Claims 6 to 8, for a load handling device in which the chassis on which the jib is pivotable is itself rotatable, the device further comprising at least one operator which is guided by a sensor sensitive to the orientation of the said chassis and which is hence capable of modulating the voltages delivered by the Wheatstone bridges before they enter the adder.

10. A device according to Claim 9, comprising a further operator capable of modulating the reference voltage as a function of the orientation of the pivoting chassis before it enters the comparator.

11. A device substantially as hereinbefore described, with reference to and as illustrated by the accompanying drawings.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1980. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.